Surface and Atmosphere Radiation Budget (SARB)

Clouds and the Earth's Radiant Energy System (CERES)
Science Team Meeting at Newport News (24-26 April 2007)

T. P. Charlock (NASA LaRC)
Fred G. Rose (AS&M) *speaks later on "Synoptic" SARB*
David A. Rutan (AS&M) *WG presentation on surface albedo*
Zhonghai Jin (AS&M) *speaks later on snow grain retrieval*
. **Seiji Kato** (H.U.) - modification of LaRC Fu-Liou code
Wenying Su (H.U.) - *speaks later on surface UV and SARB-UKMO GCM*
Lisa H. Coleman, Thomas E. Caldwell, Scott Zentz (SAIC) - Data Management

D. Fillmore, W. Collins (NCAR) MATCH
Ken Rutledge (AS&M) **-** COVE ocean platform

SARB/SOFA Working Group Wed. AM:
Joint with Cloud WG for Inamdar (GOES LST); separate for surface albedo

www-cave.larc.nasa.gov/cave/ or goggle "CERES CAVE"
Easy to use subsets of data, on line radiative transfer, ocean albedo tables…

1. Review of Surface and Atmosphere Radiation Budget (SARB) computation
2. Aerosol problems with Aqua CRS Edition 2A; will correct as Ed 2B
3. AOT input check for Terra CRS Ed2B and Aqua CRS Ed2A at SURFRAD sites
4. Surface fluxes: Retrieval vs measurements and measurements vs measurements

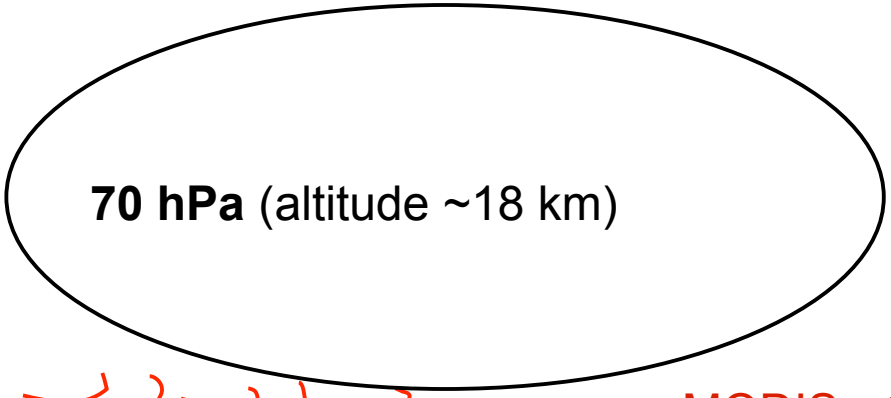
    Instantaneous accuracy

    Interannual Variability
5. Cloudy-sky fluxes: Why we need CALIPSO
6. Land surface albedo
7. Invitation to the ice box: Cryosphere surface albedo

Ungridded SARB vertical profile at ~2,000,000 CRS footprints/day

Langley Fu-Liou radiative transfer: Kato 2005 SW upgrade, retains Kratz-Rose window

NCEP O3(z)
Mostly from SBUV/2



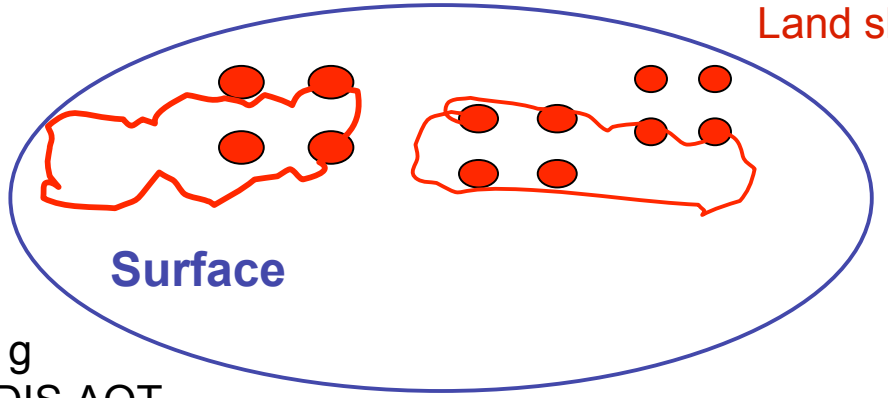
MINNIS modis

GSFC NWP

Modis Atmosphere Team

MODIS ~1km pixels provide
Cloud properties (almost always)
Aerosol AOT (sometimes)
Land skin temperature (if clear)

GEOS4 T(z), q(z), surface wind
Wind speed affects ocean surface albedo



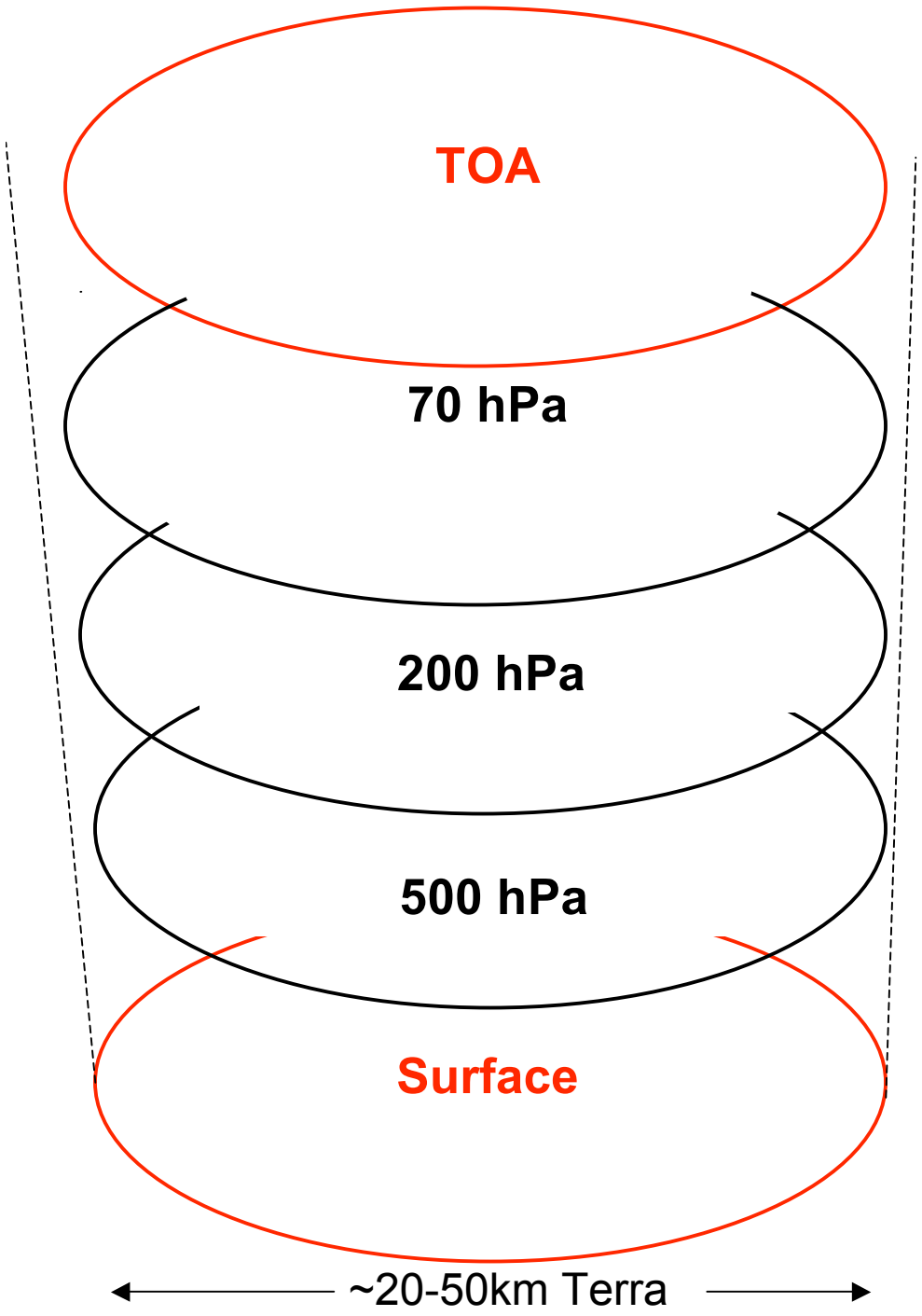
Collins NCAR

Wielicki
Loeb
Priestley

MATCH aerosols
Always used for SSA & g
Used for AOT if no MODIS AOT

~20-50 km

Large CERES footprint for TOA flux



CERES CRS: Surface and Atmosphere Radiation Budget (SARB) Product

Tuned fluxes at all 5 levels
All-sky & Clear-sky, Up & Down,
SW and LW

Surface & TOA also have Untuned fluxes
Fluxes with aerosols
Pristine fluxes (no aerosols)

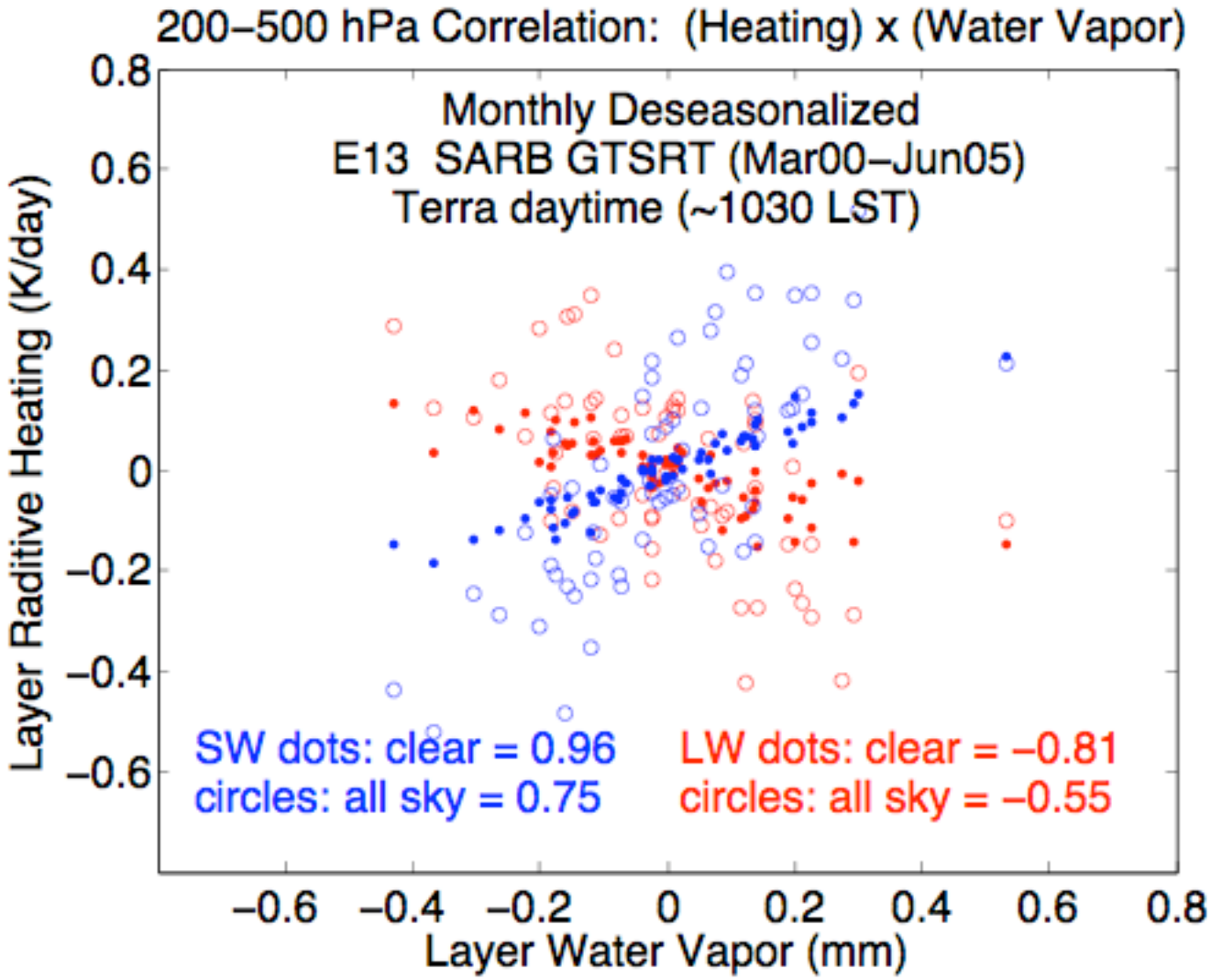
Aerosol forcing for all-sky & clear-sky

Tuning does NOT yield a perfect match to TOA observations.

Parameters adjusted when clear:
Skin temperature, aerosol AOT, precipitable water (PW)

Parameters adjusted when cloudy:
LWP/IWP, cloud top temperature, cloud fractional area within footprint

Example: using time series of flux profiles at a single site



SARB footprint (FOV) calculations are checked for Terra/Aqua/surface/TOA

- reflect more SW at TOA than observed by CERES (~3-5%) --- ocean

  Evidence for a similar tale over the clear Antarctic Plateau

- transmit more SW to surface for all-sky (~2%) & clear-sky (0-1%) --- land

  Interannual variability for all-sky SW is quite good.

  Interannual variability of snow albedo effect is good.

  ~~Aerosol forcing has some credibility as seasonal mean~~

  but not for heavy dust sites, where

  aerosols spoil cloudy calculations.

  Schuster will show SARB results for COVE platform

- have less surface LW down than PIR (~10 Wm-2) --- land

- emit more daytime OLR than CERES (0-2 Wm-2)

  And hint at possible drift in observed daytime OLR record

Gridded 24-hour SYNI now under testing; PAR and UV checked independently

www-cave.larc.nasa.gov/cave/ or goggle "CERES CAVE"

Untuned Aqua CRS Ed2A for 2003 at COVE				
All-sky flux	Observed (Wm-2)	Sample (N)	Bias	RMS
LW Down SFC	334.7	660	9.3	18.8
LW Up SFC	389.0	581	20.1	25.2
SW Down SFC	537.9	300	-13.9	80.8
SW Up SFC	29.9	260	1.7	18.9
LW Up TOA	232.7	676	3.8	9.3
SW Up TOA	253.0	321	20.2	29.6

www-cave.larc.nasa.gov/cave/ or goggle "CERES CAVE"

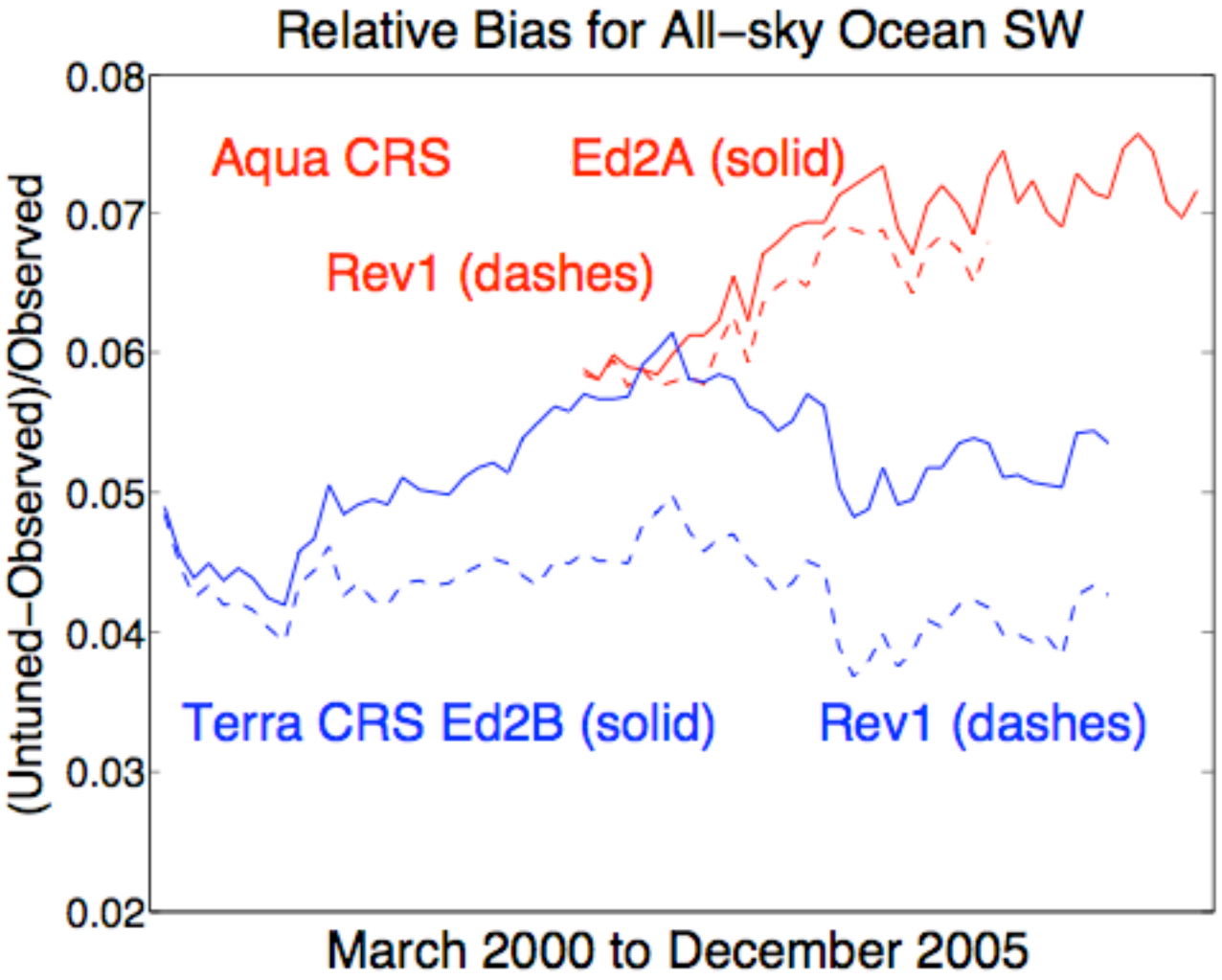
Tuned Aqua CRS Ed2A for 2003 at COVE				
All-sky flux	Observed (Wm-2)	Sample (N)	Bias	RMS
LW Down SFC	334.7	660	9.3	18.7
LW Up SFC	389.0	581	18.1	23.6
SW Down SFC	537.9	300	2.7	85.7
SW Up SFC	29.9	260	2.6	19.0
LW Up TOA	232.7	676	2.6	5.2
SW Up TOA	253.0	321	5.7	11.0

Untuned Aqua CRS Ed2A for 2003 at CAVE (CVS)

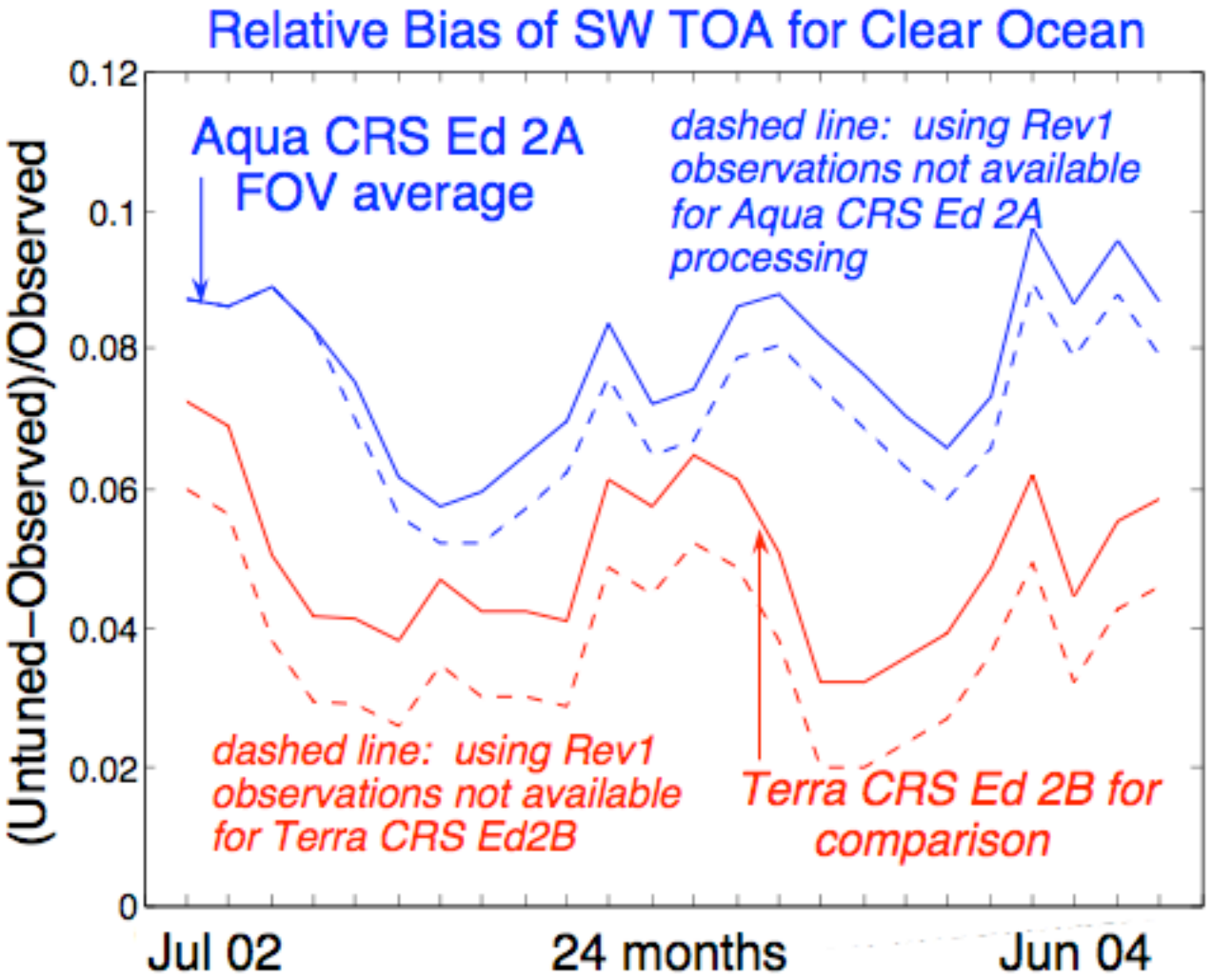
All-sky flux	Observed (Wm-2)	Sample (N)	Bias	RMS
LW Down SFC	274.6	21288	-7.3	24.7
LW Up SFC	310.7	10911	-4.9	23.8
SW Down SFC	454.1	12385	6.8	105.9
SW Up SFC	107.3	6195	-23.4	50.2
LW Up TOA	219.6	25582	0.4	8.8
SW Up TOA	259.7	12220	7.1	25.0

Untuned Aqua CRS Ed2A for 2003 at CAVE (CVS)

Clear-sky flux	Observed (Wm-2)	Sample (N)	Bias	RMS
LW Down SFC	239.3	3179	-11.2	19.5
LW Up SFC	284.0	2147	-0.3	14.8
SW Down SFC	645.6	1406	1.2	33.9
SW Up SFC	135.5	679	-25.6	36.9
LW Up TOA	246.0	4029	0.0	5.2
SW Up TOA	201.7	1402	-0.4	6.0



CRS: SARB statistics from the raw field of view (FOV) -- not gridded


Relative Bias of SW TOA for Clear Ocean
(Untuned−Observed)/Observed
0.12
0.1
0.08
0.06
0.04
0.02
0
Aqua CRS Ed 2A
FOV average
dashed line: using Rev1
observations not available
for Aqua CRS Ed 2A
processing
dashed line: using Rev1
observations not available
for Terra CRS Ed2B
Terra CRS Ed 2B for
comparison
Jul 02
24 months
Jun 04

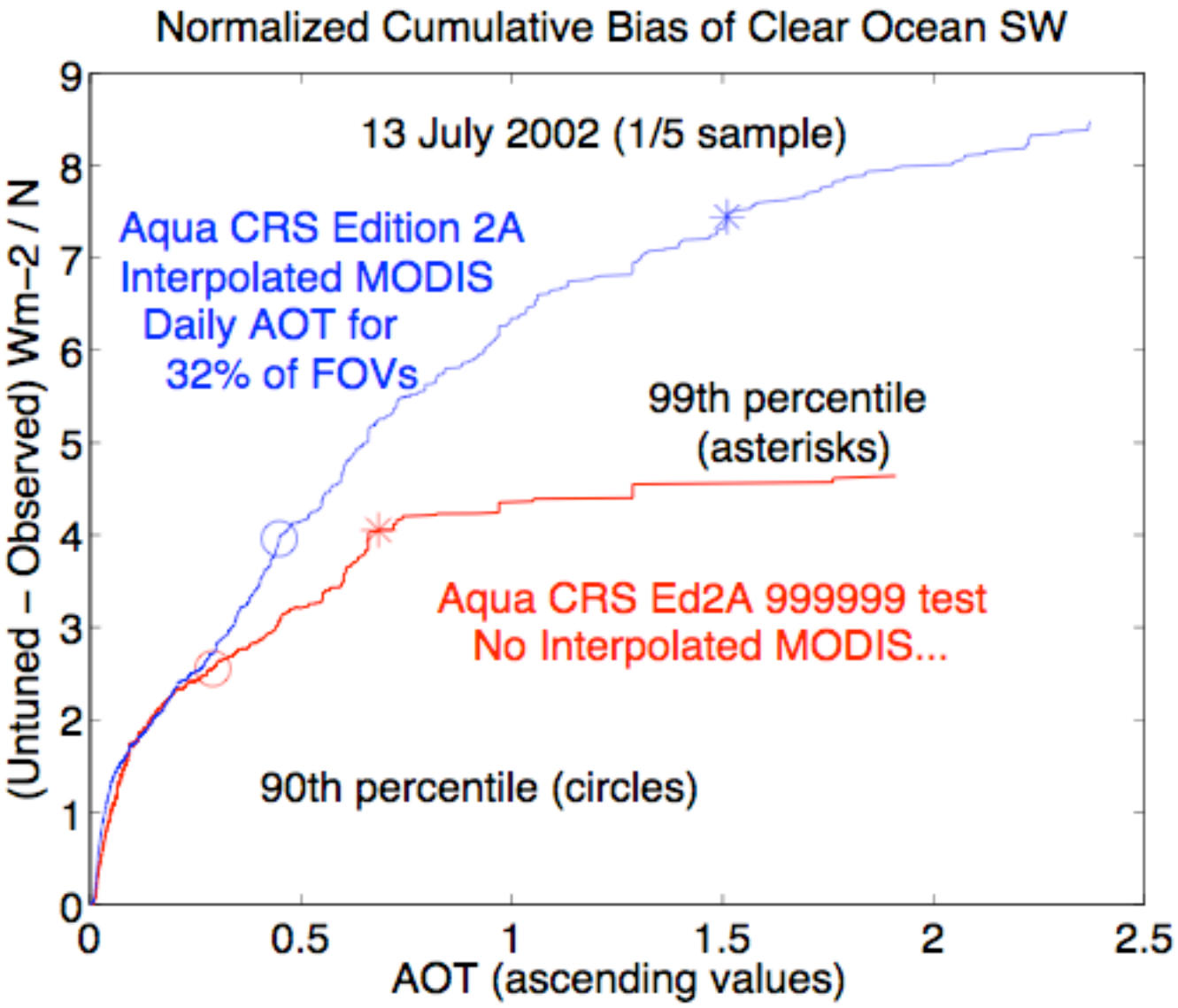
Clear Ocean During Day:
Bias of Calculated SW up at TOA and AOT Source

Aqua CRS Edition 2A (here all FM4)

Bias = (Untuned SW at TOA) - (Observed SW at TOA)

Conclusion: Aqua CRS Ed2A interpolation for MODIS Daily Average AOT has defects.

Source of AOT	**Bias**	**RMS**	**AOT**	**FOV**
	Wm-2	Wm-2	vis	(N)
13 July 2002				
MOD04 Instantaneous	2.7	5.4	0.08	13872
Interp MODIS Daily Avg	17.2	28.5	0.32	9549
1 September 2002				
MOD04 Instantaneous	4.9	6.8	0.09	12665
Inter. MODIS Daily Avg	3.0	9.5	0.14	12116
2 March 2003				
MOD04 Instantaneous	3.9	6.0	0.10	11421
Interp MODIS Daily Avg	23.8	35.1	0.44	3275


Normalized Cumulative Bias of Clear Ocean SW
13 July 2002 (1/5 sample)
Aqua CRS Edition 2A
Interpolated MODIS
Daily AOT for
32% of FOVs
99th percentile
(asterisks)
Aqua CRS Ed2A 999999 test
No Interpolated MODIS...
90th percentile (circles)
(Untuned – Observed) Wm–2 / N
AOT (ascending values)
0
1
2
3
4
5
6
7
8
9
0
0.5
1
1.5
2
2.5

NOAA SURFRAD sites have MFRSR spectral AOT observations

in addition to quality broadband radiometry.

We use MFRSR at sites below (except Desert Rock and Fort Peck)

for a look at SARB AOT inputs.

ille, IL] [Boulder, CO] [Desert Rock, NV] [Fort Peck, MT] [Goodwin Creek, MS]
State, PA] [Sioux Falls, SD]

www-cave.larc.nasa.gov/cave/ or goggle “CERES CAVE”

Aerosol Input over ARM E13 SGP and SURFRAD
(Bonville, Goodwin Creek, PSU, Sioux Falls, Table Mtn.)

Terra CRS Ed 2B

Source of Input	N	CRS	MFRSR
(All FOVs < 25km)	8888	0.15	0.08
MATCH	360	0.15	0.10
MODIS Instantaneous	4273	0.18	0.11
Interpolated MODIS Daily	4247	0.13	0.06

Aqua CRS Ed 2A (will be re-run)

Source of Input	N	CRS	MFRSR
(All FOVs < 25km)	4247	0.20	0.07
MATCH	806	0.10	0.07
MODIS Instantaneous	1371	0.16	0.09
Interpolated MODIS Daily	1770	0.28	0.06

Interpolation error due to CRS, not MODIS Team

SW Aerosol Forcing at ARM E13 SGP and SURFRAD
(Bonville, Goodwin Creek, PSU, Sioux Falls, Table Mtn.)

Terra CRS Ed2B and Aqua CRS Ed2A nearest FOVs
SSF scene ID and routine SARB AOT input
Mean SW insolation = 705 Wm-2 (N = 1654)

Clear sky SW condition

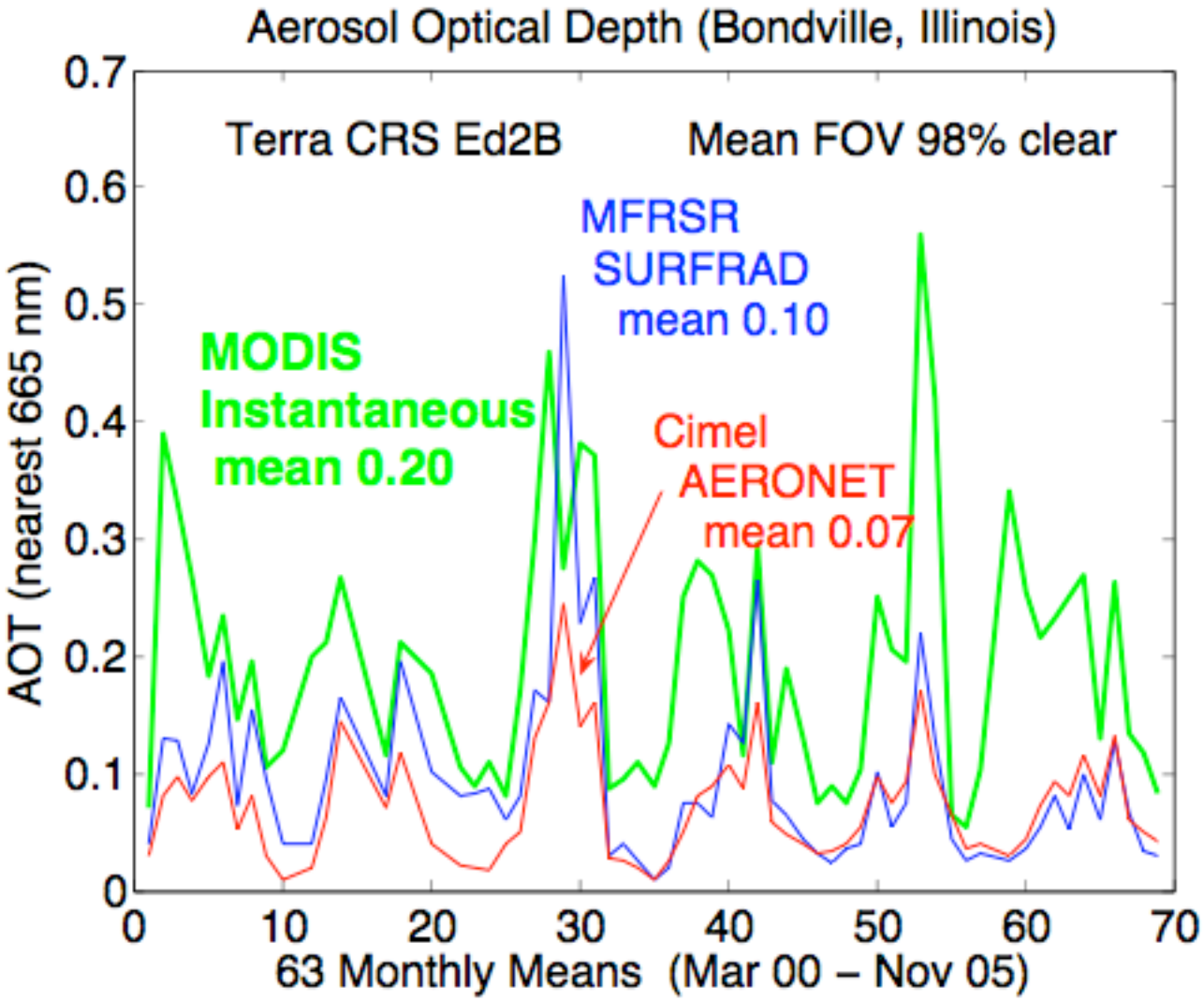
	Aerosol Forcing Wm-2	Flux Bias Wm-2	Flux RMS Wm-2
SSF scene ID/CRS AOT	-20	-0	24
MFRSR AOT adjustment	-11	8	21

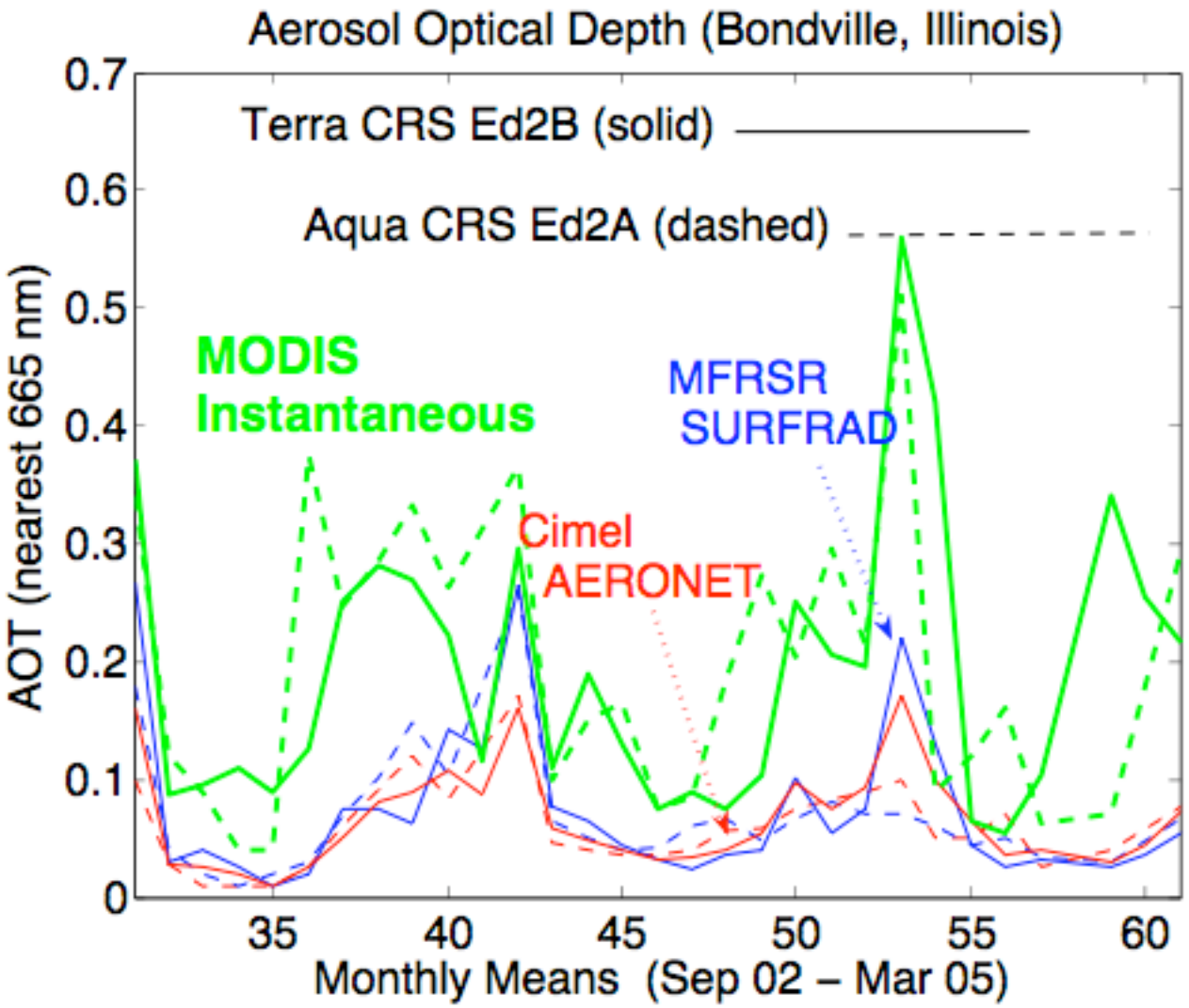
Plus surface cloud screeing:

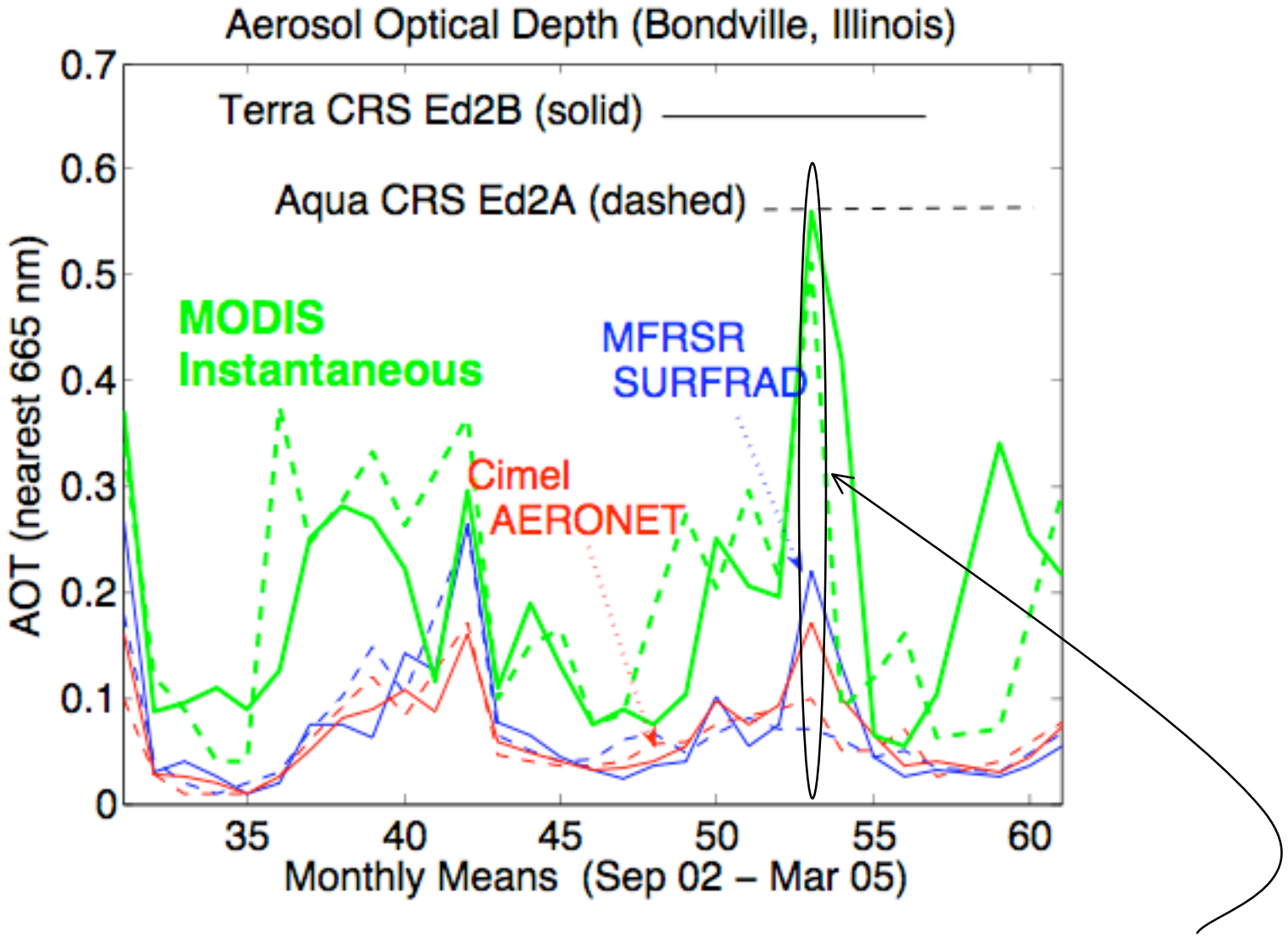
SSF scene ID/CRS AOT	*-16*	*0*	*23*
MFRSR AOT adjustment	*-9*	*7*	*20*

Terra (Aqua) bias = 0.31 (-2.93) Wm-2

Pristine (no aerosol) fluxes, AOT inputs, and with-aerosol fluxes are archived, here allowing MFRSR AOT adjustment. Flux bias (RMS) is larger (smaller) with MFRSR adjustment.


Aerosol Optical Depth (Bondville, Illinois)
Terra CRS Ed2B
Mean FOV 98% clear
MFRSR
SURFRAD
mean 0.10
MODIS
Instantaneous
mean 0.20
Cimel
AERONET
mean 0.07
AOT (nearest 665 nm)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
63 Monthly Means (Mar 00 – Nov 05)


Aerosol Optical Depth (Bondville, Illinois)
Terra CRS Ed2B (solid)
Aqua CRS Ed2A (dashed)
MODIS
Instantaneous
MFRSR
SURFRAD
Cimel
AERONET
AOT (nearest 665 nm)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
35
40
45
50
55
60
Monthly Means (Sep 02 – Mar 05)



Note the oval marking August 2004. MFRSR and Cimel and then show high AOT in morning (solid lines) but low AOT in afternoon (dashed). **MODIS Instantaneous** is excessively high and equal for both times.

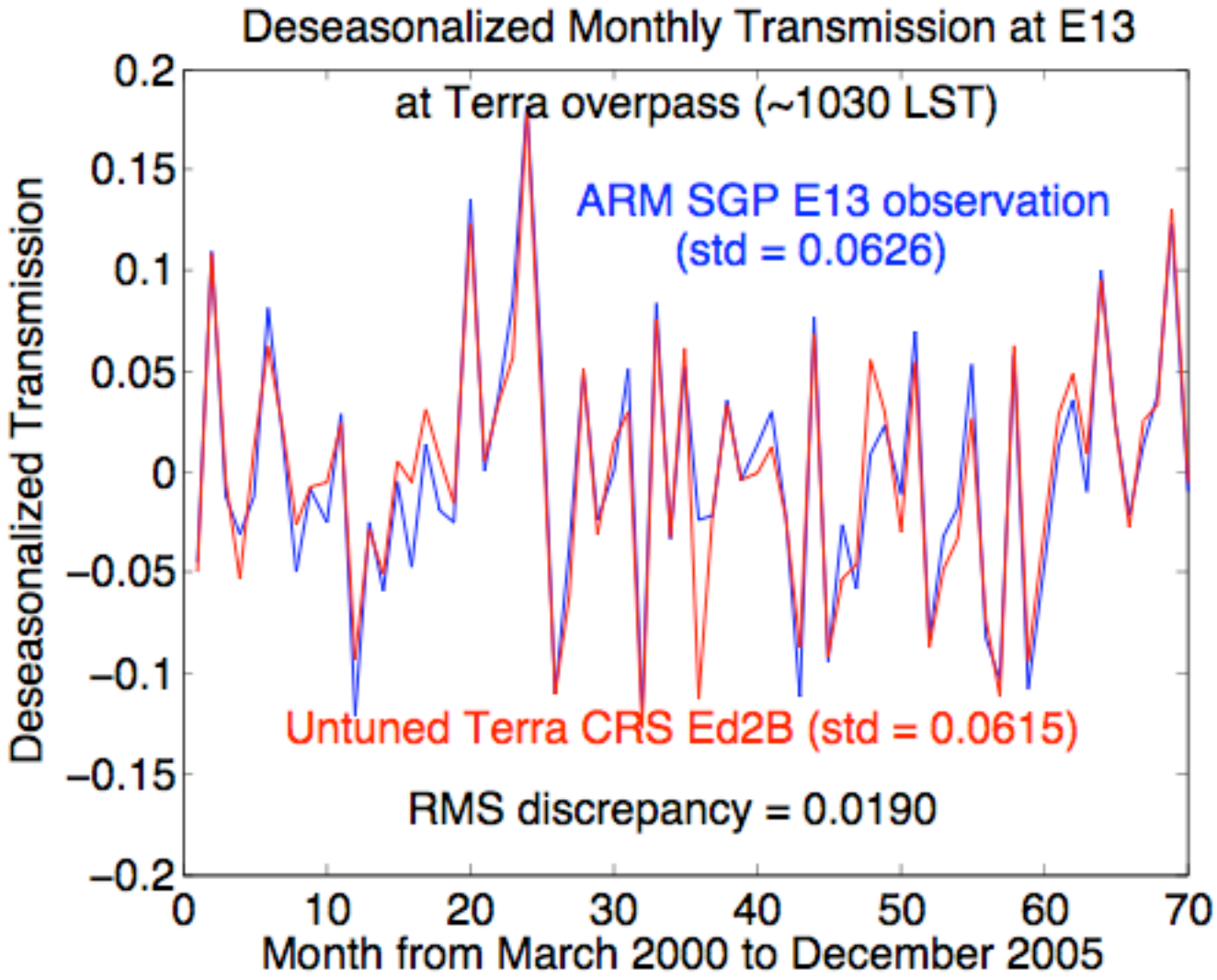
A close look at retrieved SW insolation at ARM SGP E13

Each row of a matrix has same domain.

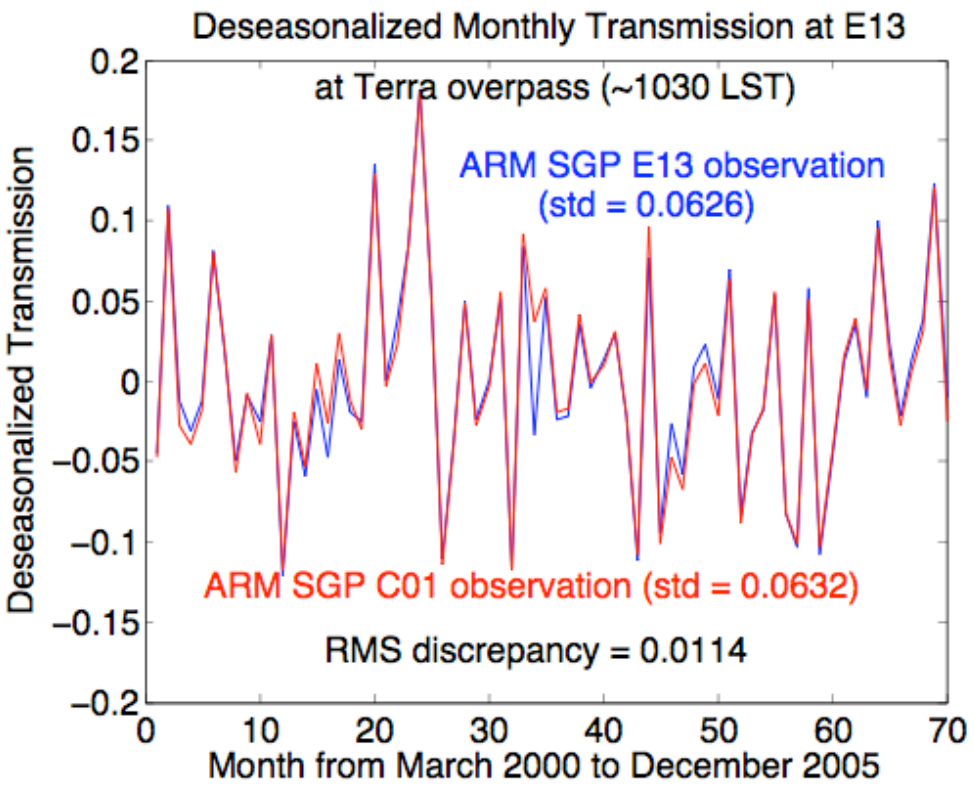
Comparison of retrieved insolation with collocated (C01 and E13) data sets.

Table is instantaneous (not deseasonalized).

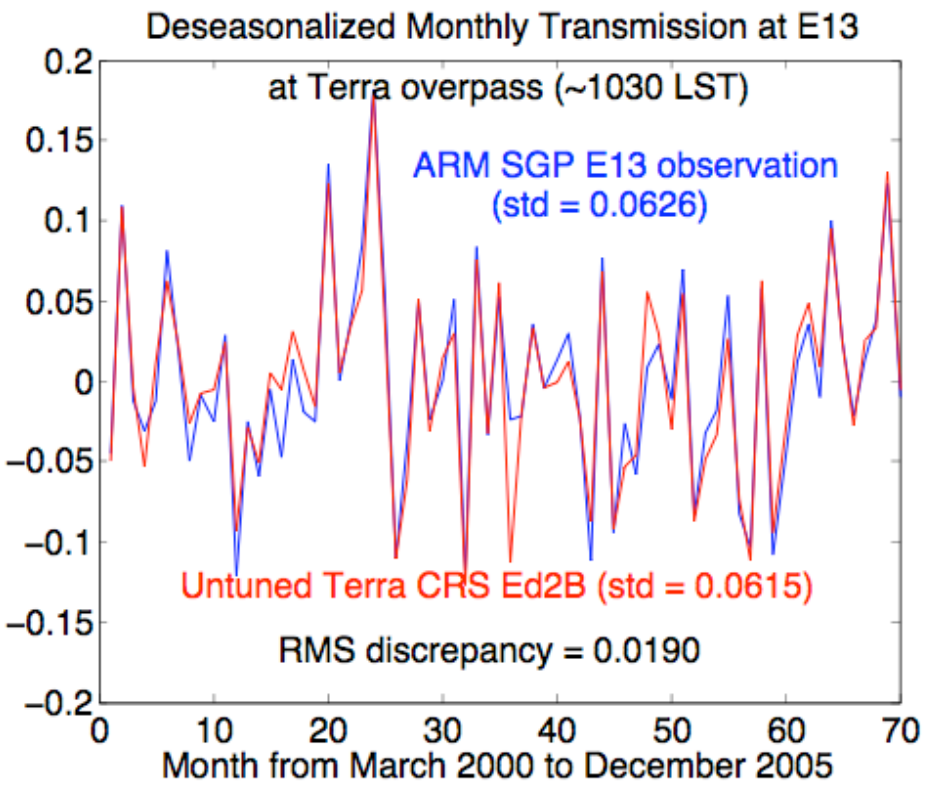
BIAS (Wm-2)	RMS (Wm-2)	of Untuned Terra CRS Ed2B
		All sky N=1876
1.7	90.6	ARM Best Estimate (BEF)
-2.8	92.3	C01
4.1	88.3	E13
		Clear SSF N=581
-2.7	16.9	ARM Best Estimate (BEF)
-7.7	*32.8*	C01 *(diffuse > 400 Wm-2 on two days)*
1.1	17.3	E13
		Clear SSF + Surface N=208
-3.6	15.0	ARM Best Estimate (BEF)
-6.7	17.3	C01
-0.6	15.6	E13
		Overcast SSF N=389
9.0	96.1	ARM Best Estimate (BEF)
7.6	97.1	C01
8.6	95.8	E13


Deseasonalized Monthly Transmission at E13
at Terra overpass (~1030 LST)
ARM SGP E13 observation
(std = 0.0626)
Untuned Terra CRS Ed2B (std = 0.0615)
RMS discrepancy = 0.0190
Deseasonalized Transmission
Month from March 2000 to December 2005
0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
0
10
20
30
40
50
60
70

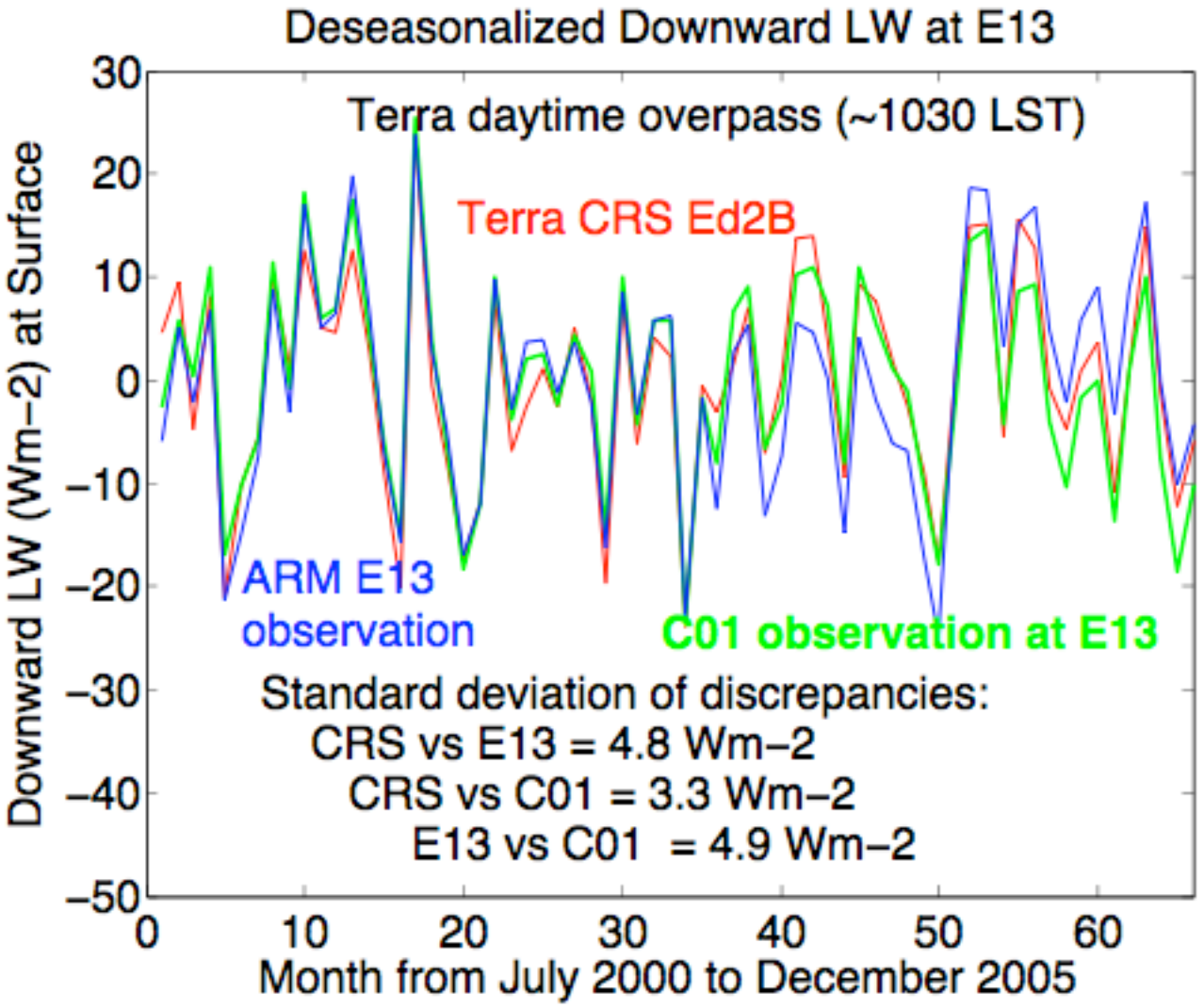
Measurements vs Measurements



Retrieval vs Measurements



RMS of deseasonalized SARB SW retrieval with E13 measurement (0.0190) is larger than RMS of deseasonalized E13 with CO1 measurements (0.014).



Instantaneous statistics for comparison:

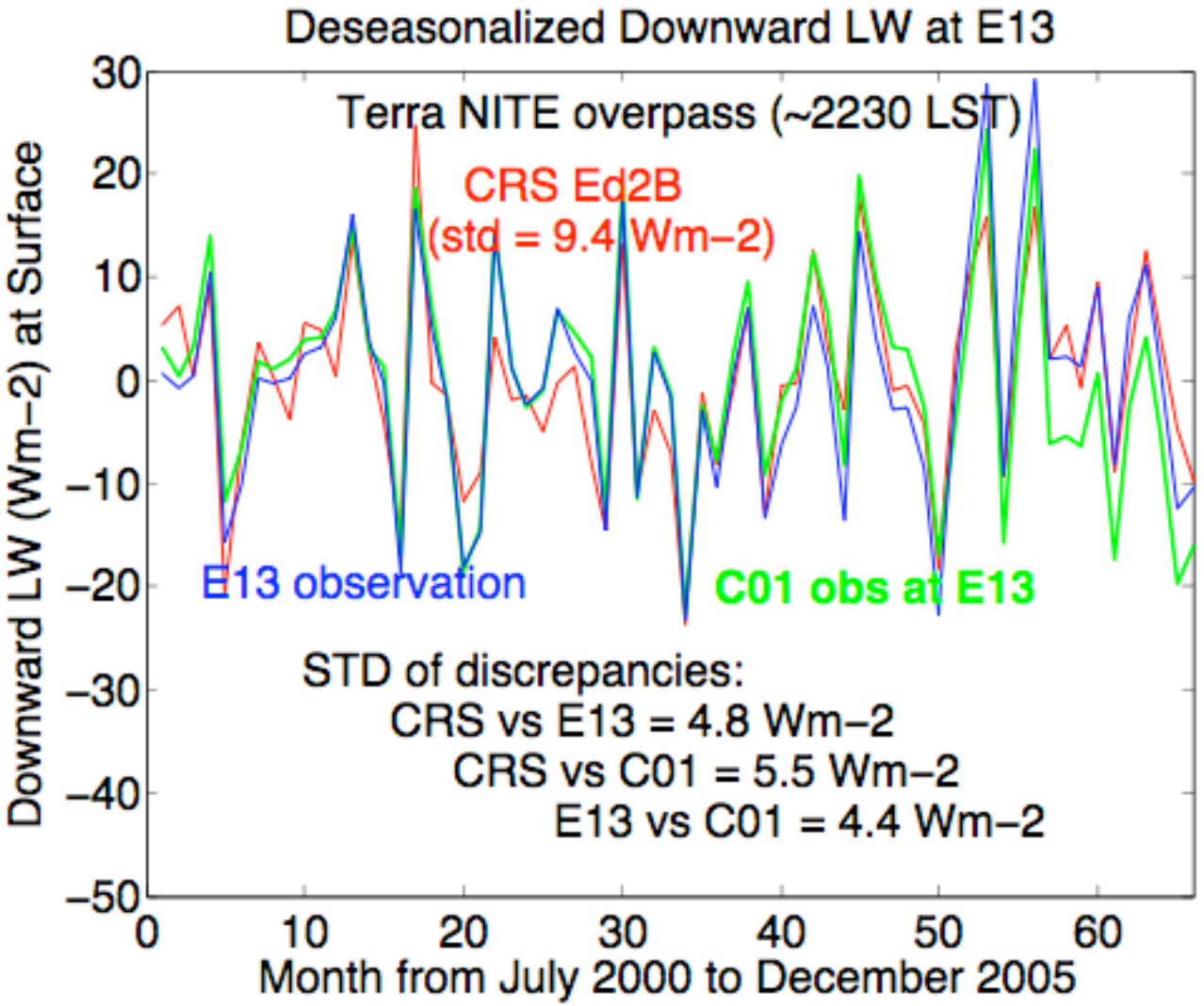
Bias (RMS) of C01 w.r.t E13 = -6.1 (8.5)

Bias (RMS) of CRS w.r.t. E13 = -13.3 (19.3)

Mean of E13 observations = 346.1 Wm-2

instrument to instrument

retrieval to instrument



Instantaneous statistics for comparison:

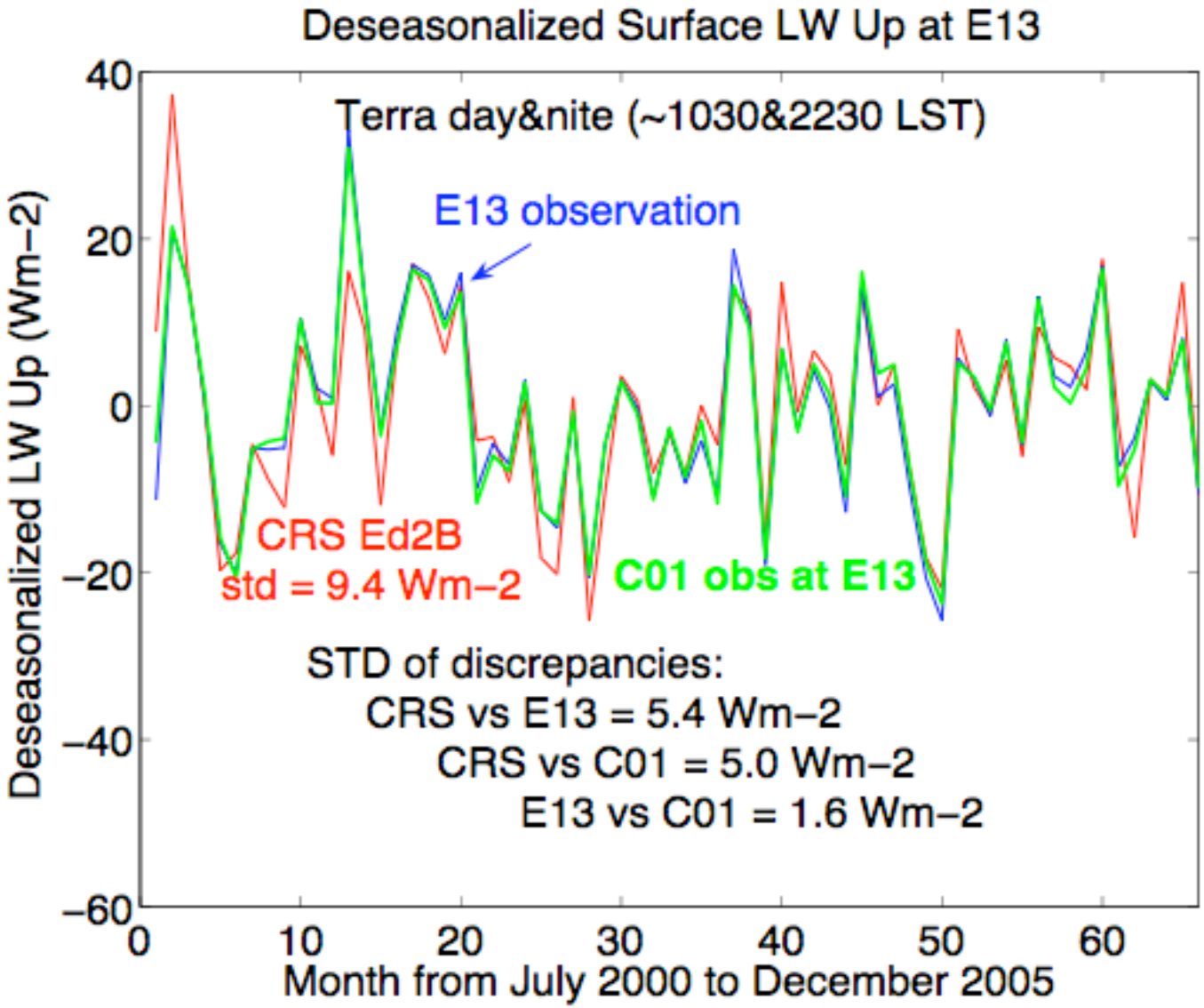
Bias (RMS) of C01 w.r.t E13 = -4.9 (6.8)

Bias (RMS) of CRS w.r.t. E13 = -7.9 (17.8)

Mean of E13 observations = 330.8 Wm-2

instrument to instrument

retrieval to instrument



Instantaneous statistics for comparison:

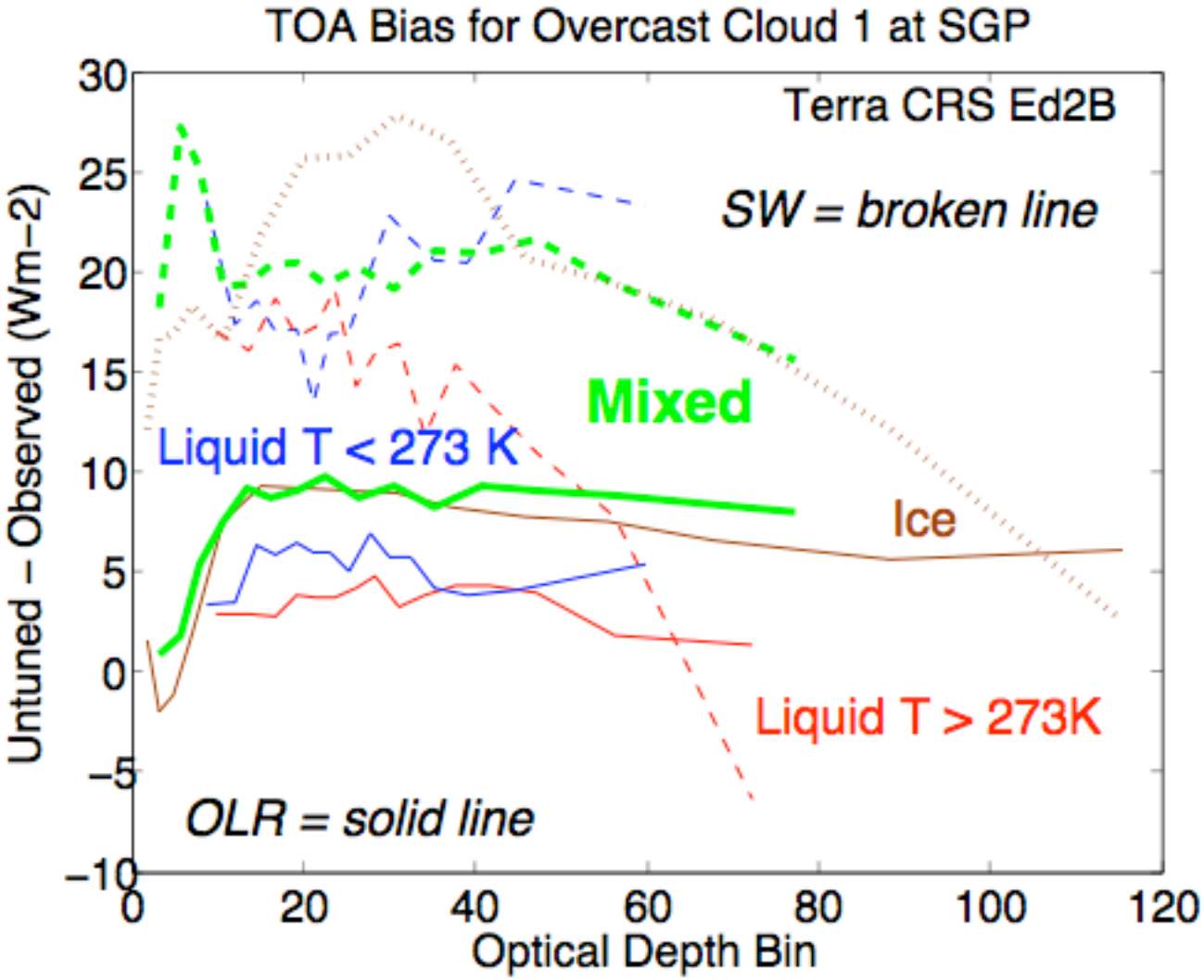
Bias (RMS) of C01 w.r.t E13 = -4.6 (6.3)

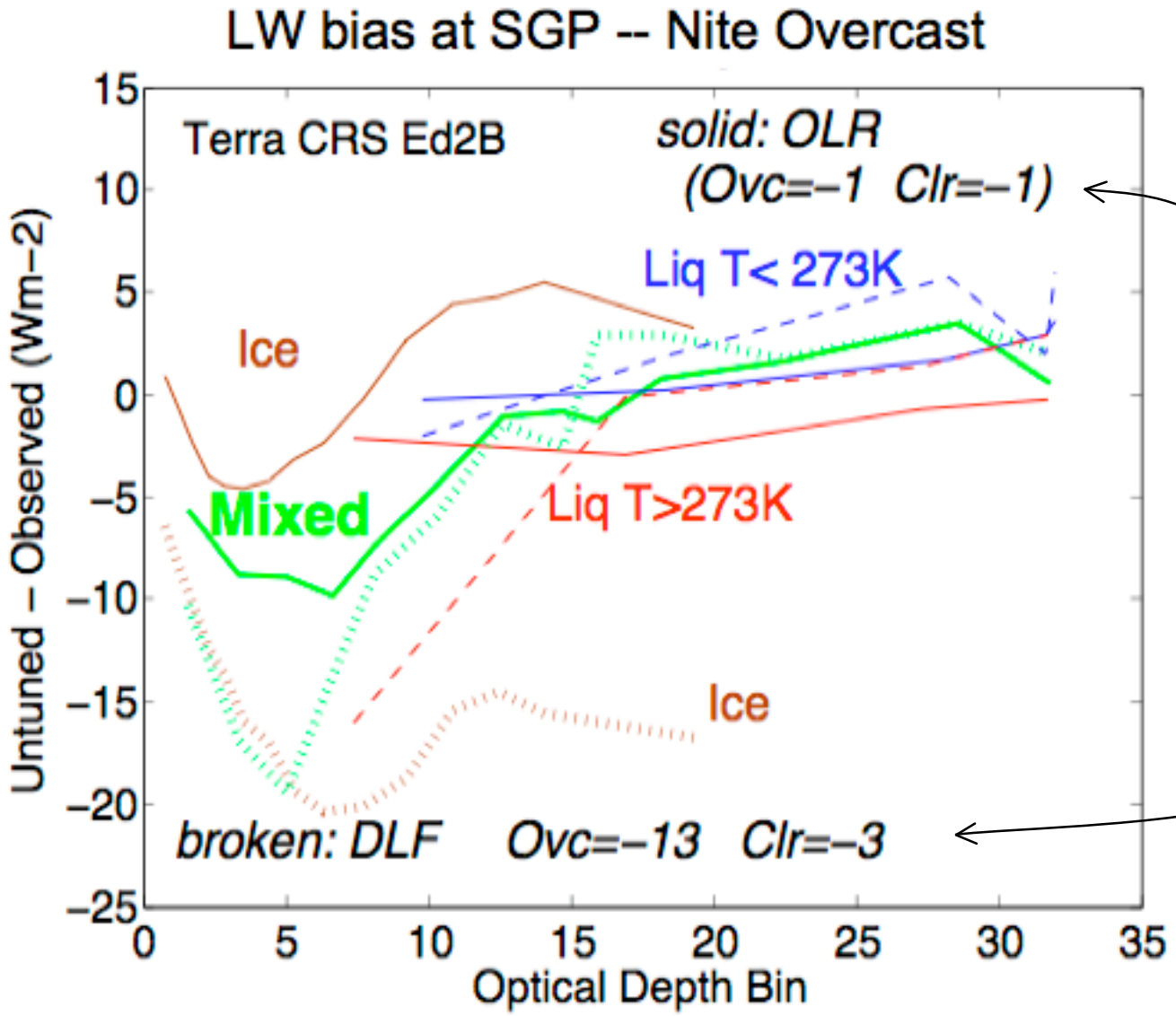
Bias (RMS) of CRS w.r.t. E13 = -5.0 (25.1)

Mean of E13 observations = 404.5 Wm-2

instrument to instrument

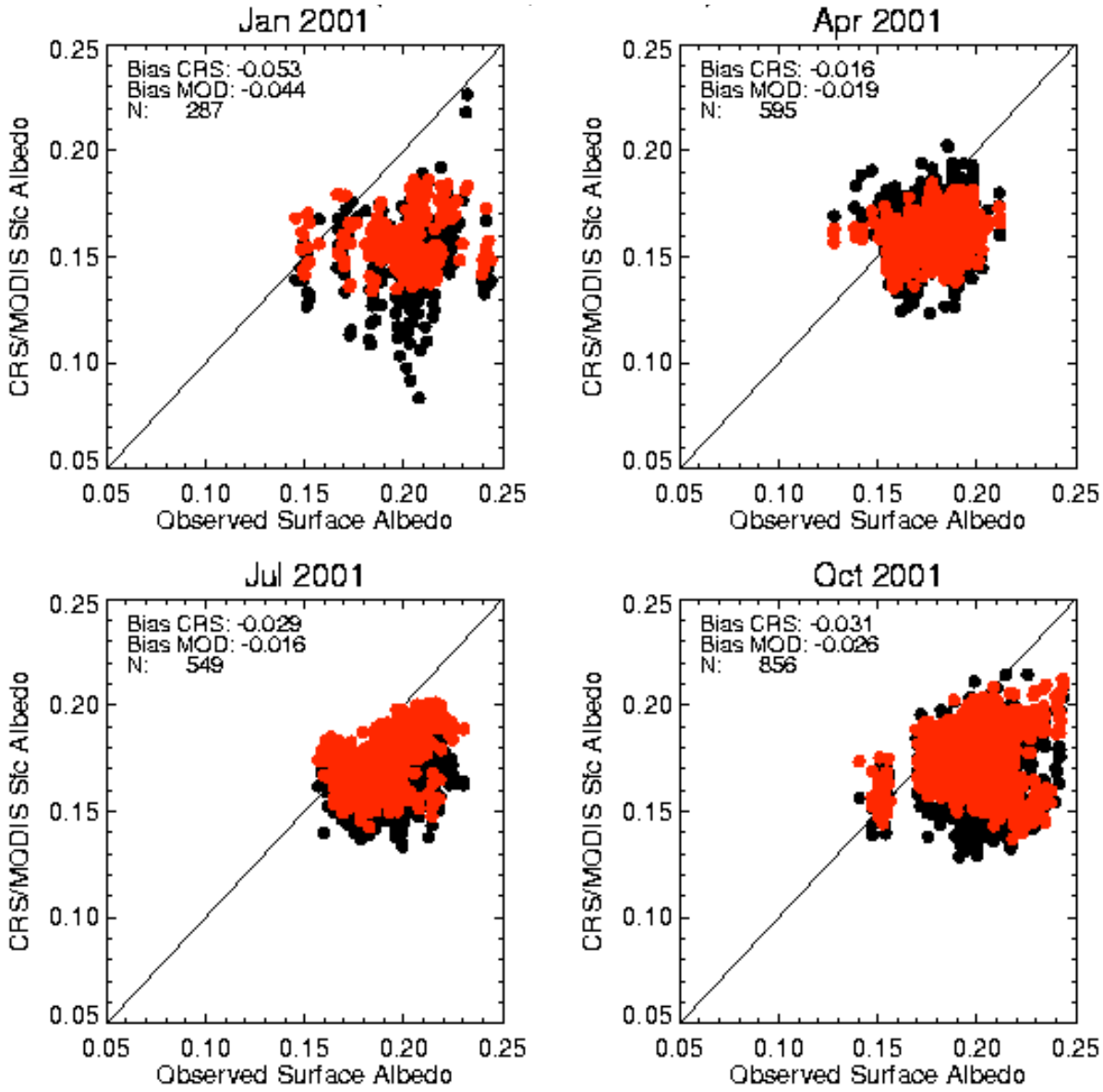
retrieval to instrument

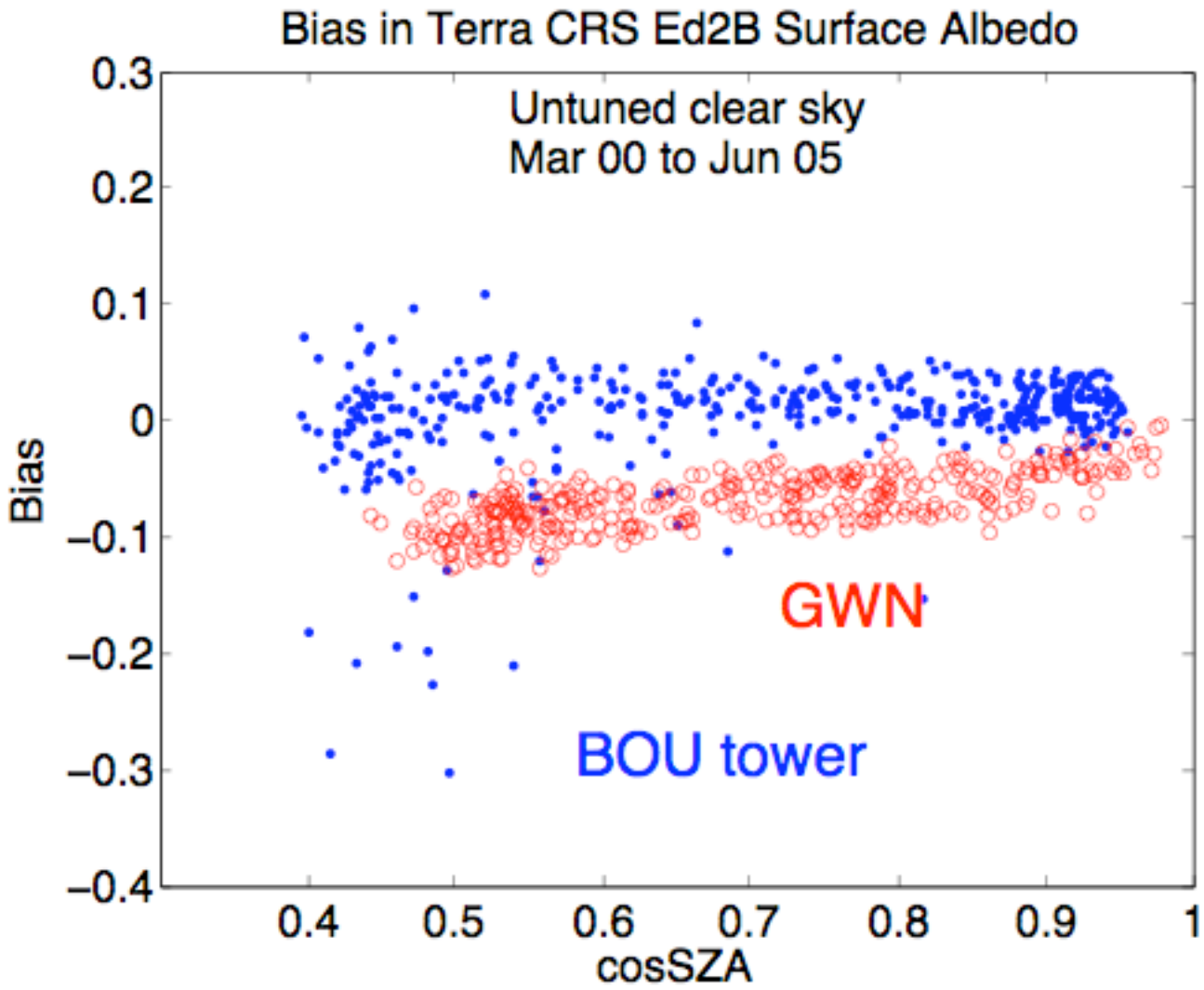

TOA Bias for Overcast Cloud 1 at SGP
Terra CRS Ed2B
SW = broken line
Mixed
Liquid T < 273 K
Ice
Liquid T > 273K
OLR = solid line
Untuned – Observed (Wm–2)
Optical Depth Bin
30
25
20
15
10
5
0
–5
–10
0
20
40
60
80
100
120

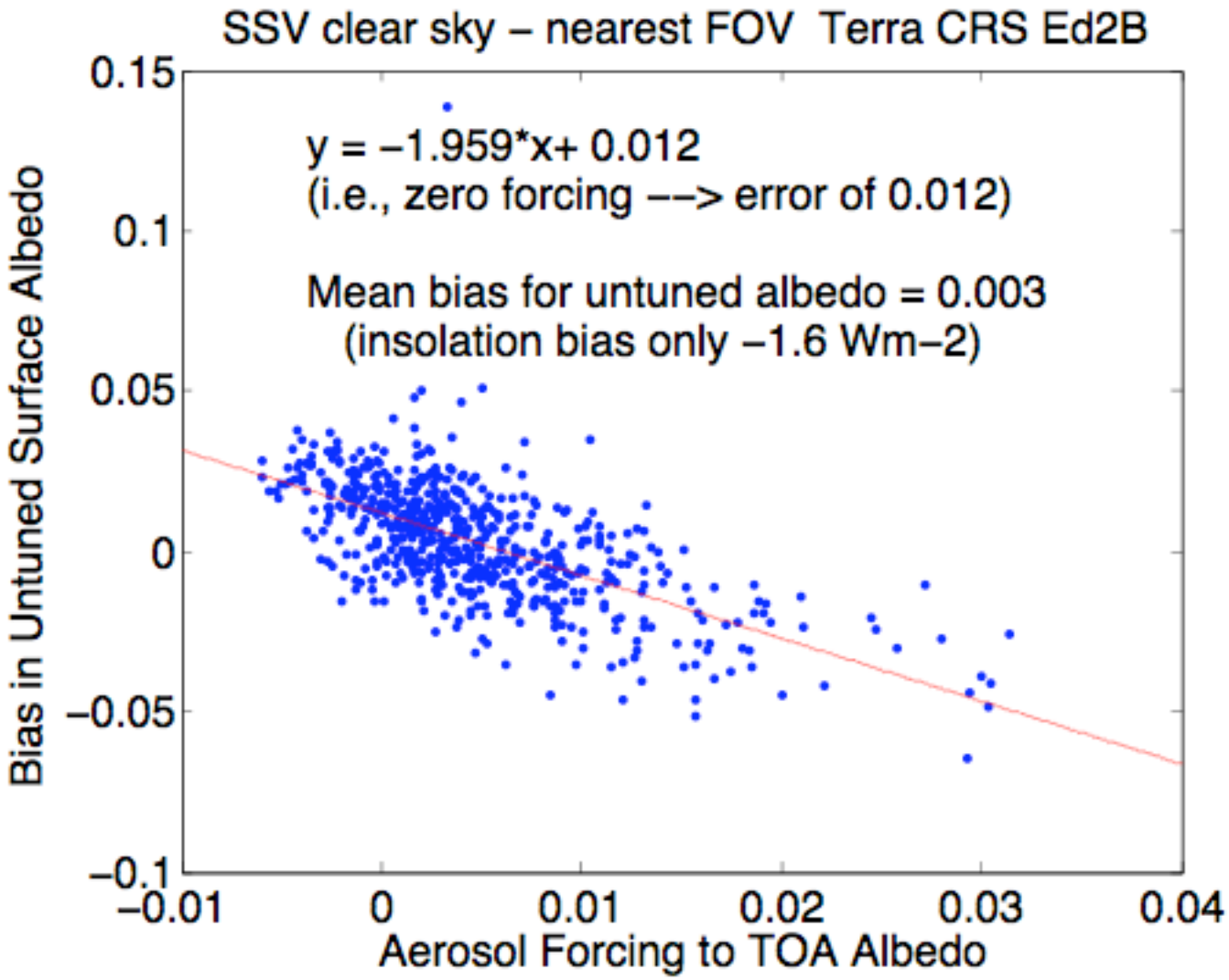


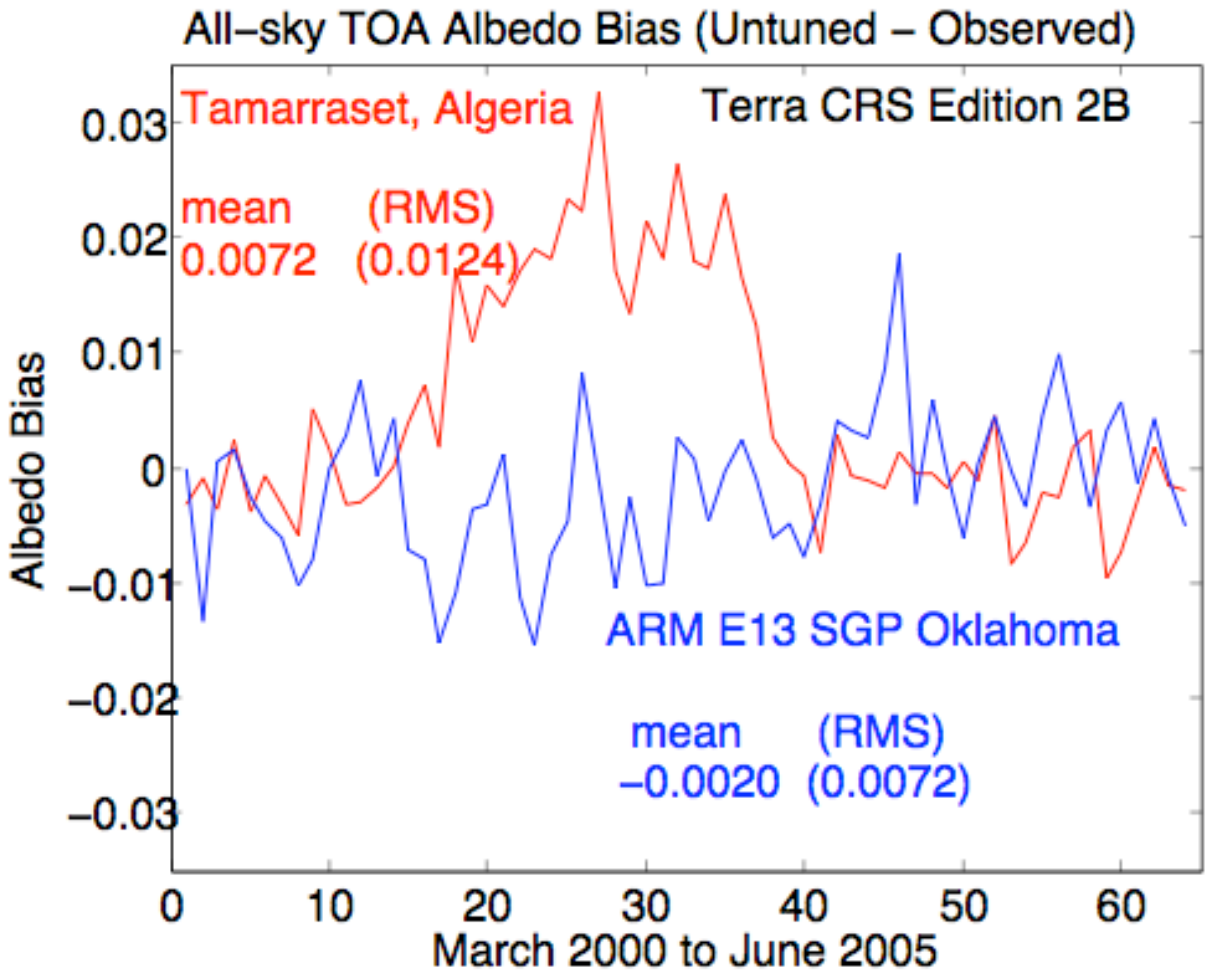
Mean biases for Overcast and Clear sky

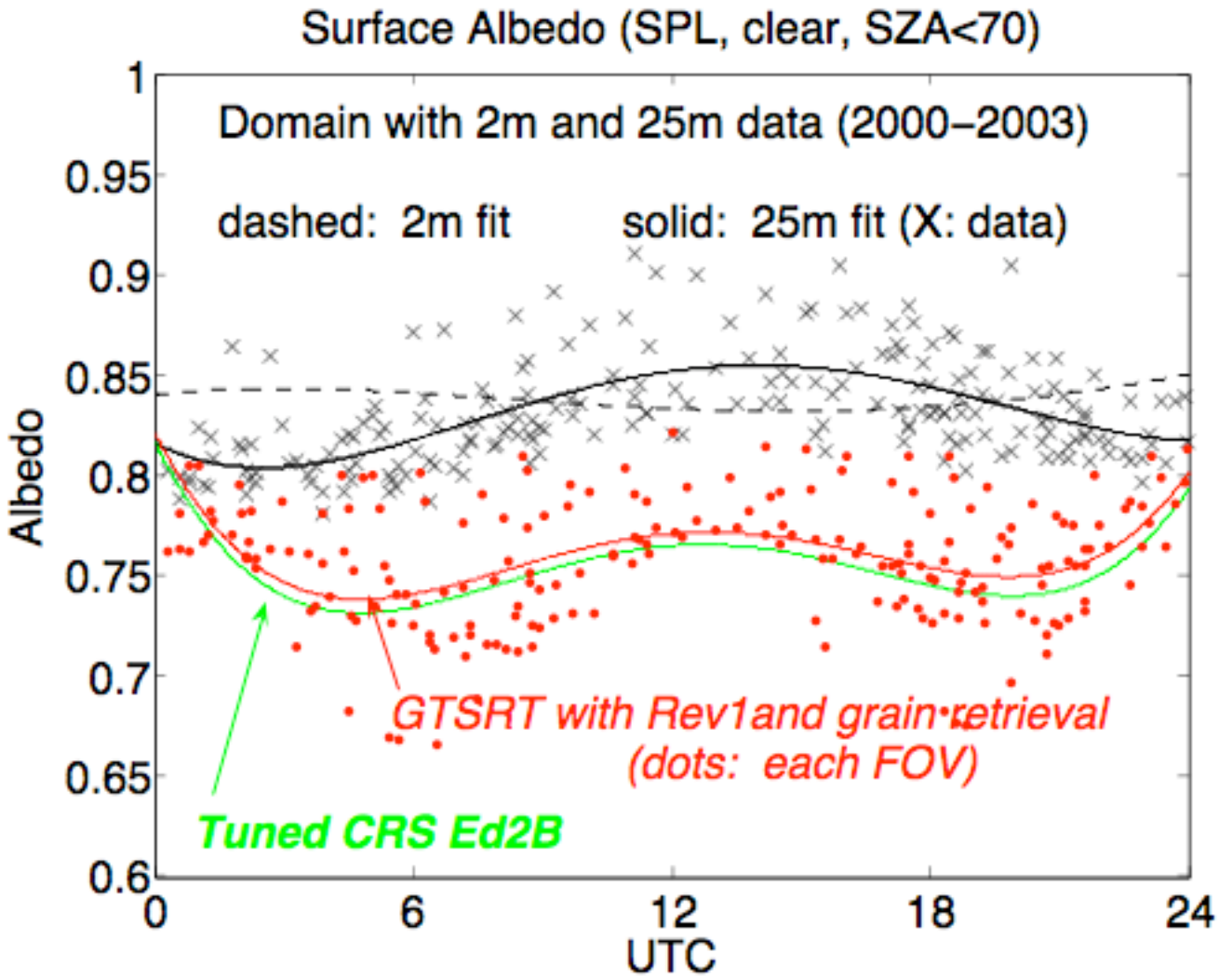
Rutan-Crystal comparison of MODIS/CERES/ARM Surface Albedo at SGP

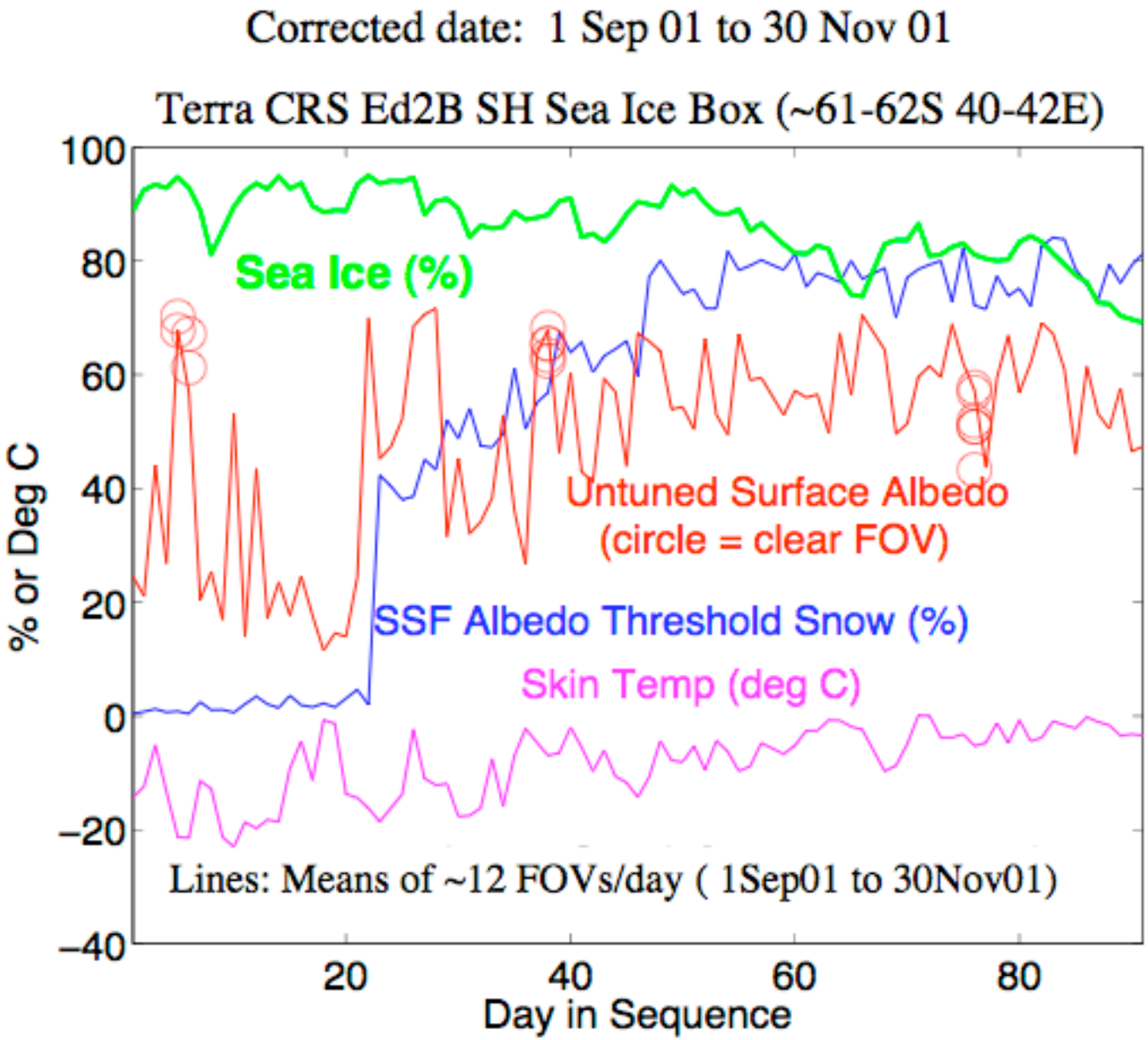



Bias in Terra CRS Ed2B Surface Albedo
Untuned clear sky
Mar 00 to Jun 05
GWN
BOU tower
Bias
cosSZA
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
0.4
0.5
0.6
0.7
0.8
0.9
1


SSV clear sky – nearest FOV Terra CRS Ed2B
y = −1.959*x+ 0.012
(i.e., zero forcing −−> error of 0.012)
Mean bias for untuned albedo = 0.003
(insolation bias only −1.6 Wm−2)
Bias in Untuned Surface Albedo
Aerosol Forcing to TOA Albedo
0.15
0.1
0.05
0
−0.05
−0.1
−0.01
0
0.01
0.02
0.03
0.04


All–sky TOA Albedo Bias (Untuned – Observed)
Tamarraset, Algeria
Terra CRS Edition 2B
mean (RMS)
0.0072 (0.0124)
ARM E13 SGP Oklahoma
mean (RMS)
–0.0020 (0.0072)
Albedo Bias
0.03
0.02
0.01
0
–0.01
–0.02
–0.03
0
10
20
30
40
50
60
March 2000 to June 2005


Surface Albedo (SPL, clear, SZA<70)
Domain with 2m and 25m data (2000–2003)
dashed: 2m fit
solid: 25m fit (X: data)
GTSRT with Rev1and grain•retrieval
(dots: each FOV)
Tuned CRS Ed2B
Albedo
UTC
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0
6
12
18
24


Corrected date: 1 Sep 01 to 30 Nov 01
Terra CRS Ed2B SH Sea Ice Box (~61-62S 40-42E)
Sea Ice (%)
Untuned Surface Albedo
(circle = clear FOV)
SSF Albedo Threshold Snow (%)
Skin Temp (deg C)
Lines: Means of ~12 FOVs/day (1Sep01 to 30Nov01)
% or Deg C
Day in Sequence
100
80
60
40
20
0
−20
−40
20
40
60
80

1. Aerosol problems with Aqua CRS Edition 2A; will correct as Ed 2B
2. Check with land photometer data shows AOT input remains problematic
3. Surface fluxes: Retrieval vs measurements and measurements vs measurments

    Instantaneous accuracy: As reported on CAVE

    Interannual Variability: Better than expected at SGP for

        downwelling SW and LW; upwelling LW not perfect
4. Cloudy-sky fluxes: Surface LW problems at nite, OLR problems in day
5. Surface albedo / aerosol relation limits ability to compute TOA albedo accurately
6. Invitation to the ice box: Cryosphere surface albedo increasing during

    spring melt (at a few places…)

SARB/SOFA meets jointly with Cloud WG for Inamdar GOES LST presentation,

    then separately for surface albedo issues,

        including Rutan's MODIS/CERES comparison